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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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INFORMATION CIRCULAR

INSTALLATION OF HIGH-TENSION POWER CIRCUITS IN COAL MINES

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BY

E. J. GLEIM

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

INSTALLATION OF HIGH-TENSION POWER CIRCUITS IN COAL MINES[1]

By E. J. Gleim[2]

INTRODUCTION

In April 1932, the Bureau of Mines published Information Circular 6595, entitled "Data in Reference to Installation of Cables in Shafts and Boreholes", in which were described methods followed in various sections of the United States when electrical circuits are taken into mines by means of cables suspended in shafts and boreholes. In view of the present tendency to extend high-tension cables along entries and other passageways from the bottom of the shaft, borehole, or other point of entrance to coal mines rather than over the surface, it is deemed that the various methods of installing such cables deserve careful consideration, particularly in mines in which gas and coal dust contribute to explosion hazards. This is especially true of localities where there is an inclination to restrict the extension of 2,300- and 4,000-volt circuits into the mines. Probably it is feared that accidental contact with the cables of such circuits may result in more serious shock than with lower voltages; also, it is possible that new circuits are regarded merely as explosion hazards additional to those already existing, regardless of the manner in which the new circuits may be installed.

It is the firm belief of some engineers that the circuits can be installed so that they will not be damaged by wrecks or roof falls, thereby eliminating the hazard of explosion from this source while at the same time making the chance of accidental contact remote if not impossible. Moreover, some believe that fire hazards from direct-current systems can be reduced by keeping motor-generator sets close to load centers. Thus, although the alternating-current circuits would be lengthened, the size and extent of direct-current circuits would be kept to a minimum.

Although some coal companies prefer to keep substations on the surface, extension of high-voltage circuits aboveground instead of in the mine, as substations are moved with change in load centers, in many instances would prove to be the more costly method. In addition to the cost of a new borehole for each new position of substation, there is the cost of the additional overhead line construction. When the surface rights do not belong to the coal company, obtaining right of way in some districts may prove to be difficult and prohibitive in cost for the overhead line. If the mine is near an industrial center, it may mean that an overhead line would have to cross railroad tracks and highways and therefore a more substantial construction would be required. Then, too, the overhead line must be constructed to withstand wind and sleet storms, and consideration must be given to protection against lightning.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7044."

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What might be considered a proper installation in one mine might prove to be an undesirable one in another mine, owing to the different conditions to be met. However, in recent years the construction of cables and methods of installing cables have been improved. This makes for safer installations. Therefore, it is the purpose of this paper to discuss various types of installations made in mines and some recent developments in cable construction and installation.

Conditions to be Met

In placing power cables along mine passageways, several important questions must be answered satisfactorily if a safe and reliable installation is to be assured:

1. Is the cable likely to be damaged by electrolytic or chemical action of mine water that may be encountered?

2. Are the mechanical and electrical characteristics of the cable such that no injury to a man will be likely to follow his touching it or driving a pick into it by accident?

3. Is the cable likely to be damaged by derailed cars, locomotives, or other moving equipment?

4. Is the cable likely to be damaged by falling coal, roof, or other materials?

5. Is the cable likely to be damaged by movement of its supports due to heaving bottom or squeezes?

To provide complete protection against shock, fires, and ignitions of gas and dust entirely through the construction of the cable itself might be considered impossible or at least prohibitive in cost. However, the ideal might be approached closely by first selecting a cable whose construction is best adapted to meeting the natural conditions prevailing in the mine, and then obtaining the additional protection not inherent in the construction of the cable itself by supporting or burying it properly.

TYPES OF CABLES

The types of cables that have been employed for high-tension power circuits in coal mines may be divided into two general classes, namely; those having a metal armor and those having a nonmetallic armor. The metal-armored type includes those in which steel wires, flat steel tapes, or interlocking steel tapes are used to give protection against mechanical damage and to serve as a grounding medium. These are generally heavier and less flexible than the other type and for that reason are more difficult to install. The nonmetallic type, without metallic armor, sometimes referred to as "soft" cables, includes those in which a so-called "fibrous armor", tough rubber jacket, or composition sheath provides the outer mechanical protection.

Some electrical engineers for coal companies consider that the conditions in their mines require the protection obtained by the installation of lead-covered wire-armored or "submarine"-type cable. Others feel that their conditions are adequately met by the use of the soft type of cable.

On account of acid water and the electrolytic action of stray electric currents, the metal armor and lead covering of power cables in a mine may corrode, especially when buried in trenches. In cables armored with steel wire or tape, galvanizing may be employed in meeting the difficulties arising from excessive moisture, but this is not complete protection. On horizontally suspended wire-armored cables, it is general practice to paint the wire armor with a bituminous compound, even though the wires are galvanized. This helps to prevent corrosion of the wires in damp mine atmospheres. On the other hand, not all cables on which there is no metal armor are suitable for trench installations; that is, some are not constructed for immersion in mine water but rather are intended for suspension from the roof or rib, where they will be subjected to little or no contact with water.

Insulating compounds have been developed with properties that give considerable latitude in the choice of a cable construction best suited to the particular conditions in a given mine installation. Cable manufacturers offer compounds that combine several highly desirable qualities. For example, a compound offered by most manufacturers is highly resistant to moisture, and therefore a lead sheath is not required to prevent deterioration. Other compounds highly resistant to moisture, oils, acids, and alkalis may be procured and vulcanized over the conductor insulation for cables that must have these properties. Thus, by proper selection of compounds, a cable can be constructed suitable for mining service.

Some manufacturers offer underground cables for which the following are some of the advantages claimed:

1. Effective sealing against moisture.

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2. Insulated conductors protected against acids, alkalies, organic decay, and waters containing chemicals.

3. Strong protection against impact and abrasion.

4. Elimination of corrosion, electrolysis, and sheath losses.

5. Installation facilitated and cost reduced by light weight, extreme flexibility, and ease of handling cable.

The construction adopted for obtaining these advantages is approximately as follows:

1. The conductors are separately insulated with high-grade rubber, and rubber-filled colored tapes identify the individual conductors.

2. A circular section is obtained by the use of pre-impregnated jute fillers in the valleys between the conductors.

3. A layer of special sealing compound is placed over the cabled conductors, and in this compound is embedded a fibrous armor made of Kraft paper.

4. A layer of special sealing compound follows the fibrous armor, and over the latter is placed a strong covering of closely braided sisal or preimpregnated duck tape.

5. The cable is completed by a layer of finishing compound and a coating of mica flake.

Another development in cable recently used in trench installations is a tough outer jacket of 60-percent Hevea rubber, such as is used on mining-machine and dragline-shovel cables. This jacket is well known in the coal mining fields. It is nonporous, waterproof, and highly resistant to acid and alkali conditions - important features to be considered in the selection of cables that are to be buried. For high-voltage service, even for operating service of 2,300 volts, the manufacturer, for safety reasons, recommends a shielded cable. This type of cable is employed in a bituminous-coal mine not far from Pittsburgh, Pa., for 4,000-volt circuits serving underground substations. The individual conductors are insulated for 5,000 volts. Over this is a shielding tape of tinned copper 5 mils thick. The tapes of the three conductors are in contact with each other and are designed to serve three purposes, namely; (1) protection of workmen against shock, (2) elimination of static discharges, and (3) elimination of "hot spots" in the center of the cable by improvement in thermal conductivity. In each of the "valleys" between conductors and in contact with the shielding tapes, is a grounding conductor whose cross sectional area is about equal to one-third that of a main conductor. It is understood that these grounding conductors are not connected to ground anywhere in the mine but are carefully connected to a system ground on the surface. This was done for the express purpose of preventing the grounding conductors and shielding tapes from carrying any current that might stray from the direct-current haulage system in the event that the rail bonding becomes defective.

Some engineers specify 5,000-volt insulation for cables to be used for 2,300-volt circuits and 8,000 volts for 4,100-volt circuits. The cable manufacturer does not usually recommend this, but where continuity of service and freedom from the hazards of shock and ignition are of such vital importance, as in the operation of mines, this additional factor of safety is well worth the extra cost.

TYPES OF INSTALLATIONS

Three general methods have been followed in placing high-tension cables in mines. Each has its advantages and disadvantages from the standpoints of safety and ease and cost of installation. In the first method the cable is simply allowed to rest on the floor with little or no additional covering to protect it from damage by derailed cars or by falling material. In the second method the cable is suspended from the roof or rib, and in the third method the cable is buried in a trench cut into the rib or floor. The following paragraphs give some details regarding the three methods of installation.

Floor Installations

In these installations a metal-armored cable is usually placed close to the rib where it is least likely to be injured by slate and coal falling from the roof. In some instances, loose slate and coal may be used to cover the cable as a form of protection. The advantage of this type of installation lies chiefly in the ease and low installation cost of getting the cable into place. However, it is open to the serious objection of having the least protection against mechanical damage, particularly in those installations where the cable is placed along haulageways, as has been done in some mines. Furthermore, if steel-armored cable is used and the armor becomes distorted by a blow, the cable is subject to failure at this point because the armor is likely to be permanently deformed, pinching the insulation and ultimately resulting in its break-down. If the mine is wet, the armor may also be corroded by acid water or by electrolysis.

Suspended Cables

One method of suspending cables employs copper-clad or galvanized-steel messenger cables with metal aerial rings or clips at short intervals (18 to 24 inches) for holding the power cable. The messenger cable itself is hung from hooks driven in the roof or rib, or, in timbered entries, from hooks in the cap pieces. When it becomes necessary for the messenger cable to cross entries in which there are trolley and other power wires, one coal company dead-ends it to a post at each side of the entry being crossed; the cable is then taken through metal conduit under the track. This conduit is grounded to the messenger cable. The metal rings used to support the power cable also ground the metal armor of the power cable to the messenger cable. The latter, in turn, is grounded every 500 feet.

When the cable crosses entries or manways where there is no trolley wire, another company that uses messenger wire for support of a power cable continues the wire at the same level at the openings crossed as elsewhere; but to insure reliability of suspension in case the iron hooks should loosen and drop out, additional supports are built at these points. These additional supports consist of an iron pipe erected on each side of the passageway being crossed by the cable, and a hook of flat strap iron that is welded to each pipe holds the messenger wire at the same level as before. At this operation the power cable has an unprotected outer sheath of lead. The other company cited used lead-covered armored cable in damp or wet places, and for dry mines a 1/8-inch sheath of rubber was substituted for the lead. Joints in the cable were placed in bolted cast boxes filled with compound.

In some recent installations, three-conductor, nonmetallic, sheathed power cable has been supported on large porcelain spools hung either from steel crossbars hitched into the rib at both ends or from stub ends of rails cemented into the ribs to a depth of about 3 feet. Thus, there are no posts to be knocked out by derailed cars. The cable parallels the trolley wire; and where crossbars are used the distance between the cable and trolley wire is 18 to 24 inches, the cable being nearer to the rib. The cable is fastened at regular intervals to a spool by tie-wires to prevent too great a lengthwise movement, particularly when the power circuit is carried along entries that are not level.

Variations of the foregoing method of installation may be had according to the type of support adopted. The simplest employs straps made of flat iron 3 inches wide and 3/8-inch thick, bent to form a hook and drilled to take two lag screws. In timbered entries or gangways, these hooks are fastened at 10-foot intervals to the legs of the timber sets on the trolley-wire side of the passageway. Hooks and clamps attached to pipe or hangers fastened in the roof by expansion bolts offer another variation where the passageway is not timbered. This has been used for carrying the circuit along rock tunnels and gangways in anthracite mines. Pipe hangers with individual cable clamps suspended by insulators have been used where the circuit consists of three separate cables. Another arrangement for handling three separate cables has pin-type insulators with metal pins mounted on a piece of angle iron, which, in turn, is fastened at each end to pipe supports by means of U-bolts. This arrangement requires that the cable be fastened at each insulator.

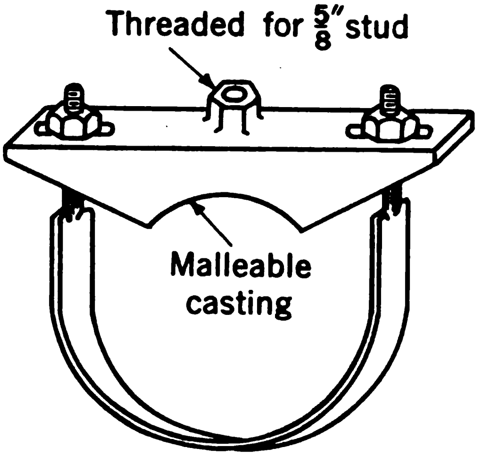

Figure 1.– Cable hanger.

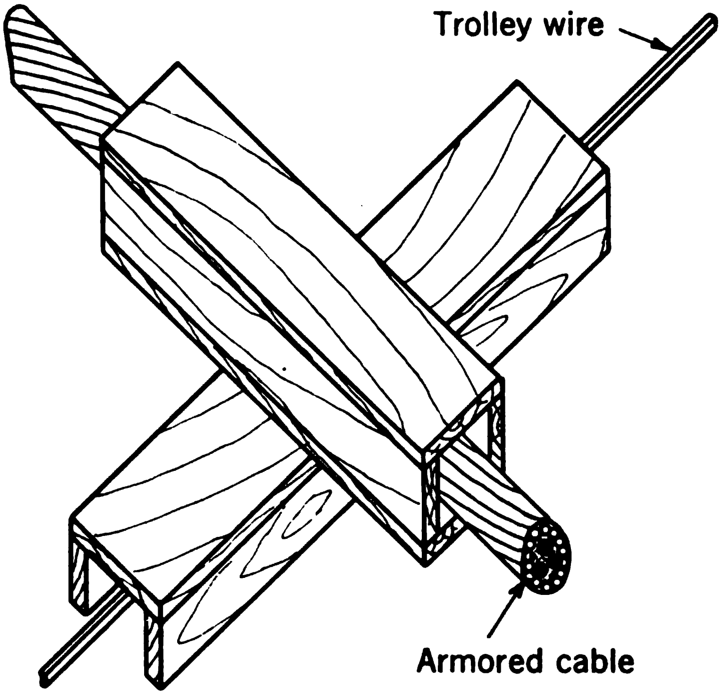

Figure 2.– Cable crossing guard.

One advantage claimed for the type of installations just described is that the cable is constantly under the observation of men passing along the entry or gangway, and any damage to it can be quickly seen and easily repaired. Any installation in which the cable supports are attached to timber sets is open to the objection that dislodgement of the timbers by a wreck may cause a short-circuit in the cable. This would be a serious hazard in a bituminous mine if a cloud of coal dust were raised during the wreck. The strength and flexibility of the messenger cable are claimed to offer considerable protection to the power cable by deflecting material falling from the roof, which otherwise might injure the cable.

When the entries and gangways to be traversed by the high-voltage cable are level or nearly so, it is often the practice to support the nonmetallic armored cable in the large porcelain spools mounted in strap-metal clevises without using tie wires to fasten the cable to the insulator except at turns where it is desirable to keep the cable from riding against the metal strap. When the cable is not tied to the insulators, it is sometimes the custom to allow the cable to be slack between insulators; then should coal, rock, or slate fall upon it, the cable can sag under the weight coming upon it while at the same time it deflects the falling material to one side. Thus, the damage to the cable would probably be much less than to one held rigidly at each support.

One coal company has designed its own supports for mounting armored power cables. This is illustrated in figure 1 and consists of a malleable casting having a 5/8-inch tapped hole for attaching it to the usual expansion bolts in the roof or to pipe extensions where the roof is high. The underside of this casting has a curve made to fit the radius of the largest cable to be supported. It is also slotted to permit accommodation of the special flattened U-bolt to the size of the cable. This type of hanger would not be suitable for the suspension of unarmored cables because of the danger of damaging them by pulling the clamp too tight, and since the hanger is not insulated, a ground or short-circuit might result.

When it is necessary to carry a power cable over a trolley wire with small clearance between them, it is advisable to protect the cable from flying trolley poles. This can be accomplished in several ways. One method makes use of a piece of iron pipe or conduit about 3 feet long fastened to the roof above the trolley wire by iron straps, the cable being incased by the pipe. In another method, the cable is boxed in and the trolley wire also is guarded with boards, as indicated by figure 2.

To insure the highest degree of safety from gas and dust ignitions, high-tension cables should not be suspended or supported along haulageways unless the roof is exceptionally good, and then only when the cables installed are protected against injury as the result of wrecks.

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Trench Installations

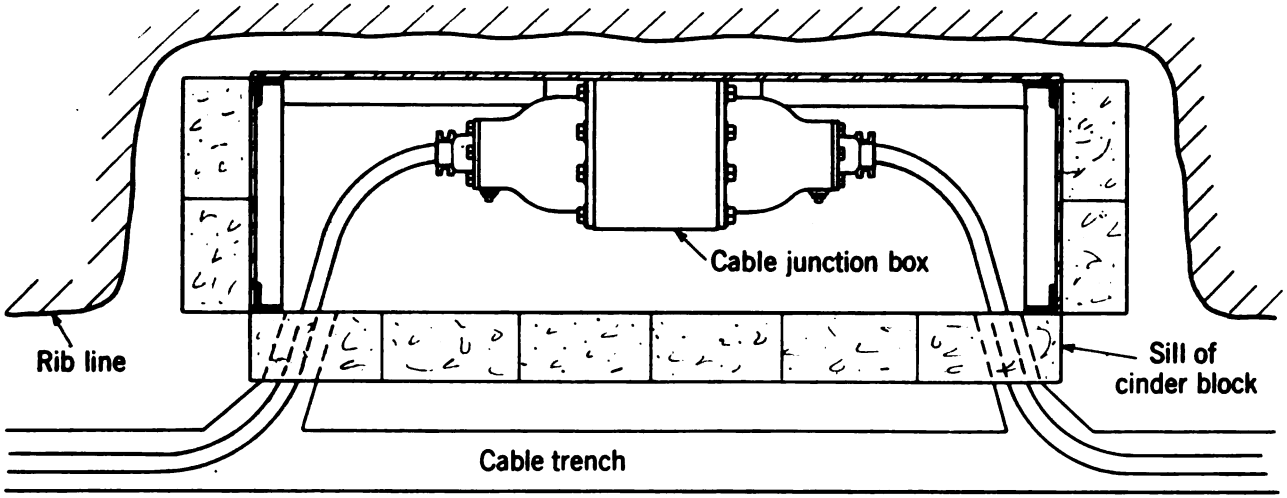
If the mine is not subject to heaving bottom, the best protection that can be given cables against mechanical damage that might otherwise be caused by derailed cars and locomotives or by falling roof, is usually obtained by burying the cables in trenches. If the mine is wet, the cable to be selected for this type of installation should be impervious to moisture and resistant to corrosion. When the cable is selected the possibility of oil entering the trench also should be considered.

When cables are buried in trenches, shock hazards are not necessarily eliminated if enough care is not given to the selection and protection of the cables. One hazard arises when the men dig drainage ditches or lower track levels. They may be unaware of the proximity of the cable and drive a pick or bar into it. The steel armor ordinarily used should not be regarded as punctureproof against such tools. If the conductors are encased in a properly grounded metallic armor of heavy steel wire or tape or are protected by shielding tapes and grounding wires, these tools may cut into the live conductors and be grounded without serious injury to the workman.

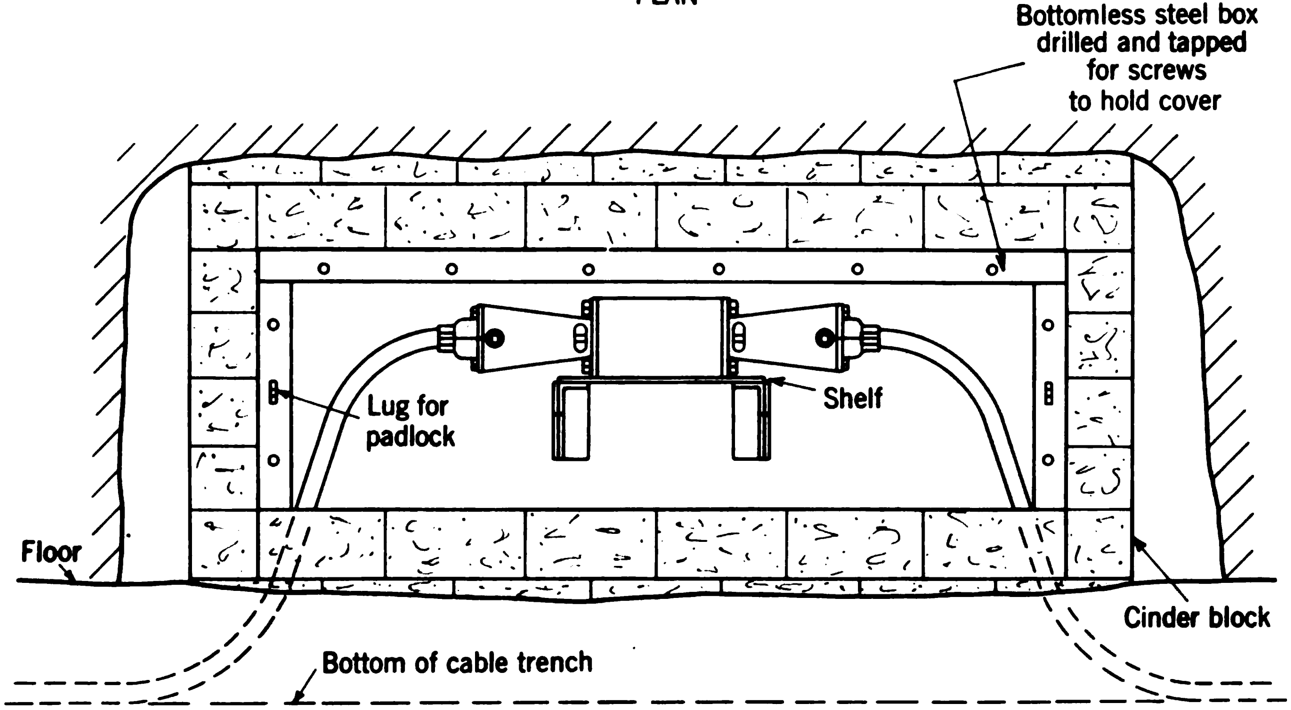
Another hazard that should not be overlooked if cables do not have metal armor or conductor shields is that a fault in such a cable may result in the flow of enough current to nearby rails or pipes through a low-resistance path to raise them to dangerous potentials. Consequently, it is highly important from the safety standpoint that cables, whether of the steel-armored or the nonmetallic type made with shields and grounding wires, have their armor or grounding wires (as the case may be) thoroughly grounded, and that circuit-breakers or other overload protective equipment be kept in working condition and properly adjusted to clear the circuit in case of cable faults.

A number of installations in different parts of the United States use a cutting machine for making the cable trenches. Generally, the trench is cut in the floor with the cutter bar turned to the shearing position, but one installation has been seen in which a horizontal cutter bar was used and the cut made in the rib along the entry. In this particular installation, a "submarine" type of armored cable was brought in along the intake airway and taken across the entry in a channel made in the roof. The open or under side of this channel was closed with sheet metal held to the roof by wooden strips. From this channel the cable ran to the shallow groove or trench cut in the rib with the mining machine. The cable was covered by filling the groove with adobe. Where it passed crosscuts, the cable was either supported on props or carried along the roof in a shallow channel cut into it.

When trenches are cut in the floor with a machine, the cutter bar usually is set to cut as far to the side as the machine adjustments will permit or as close to the rib as possible. The cut is 12 to 18 inches deep and about 6 inches wide (the nominal height of kerf). With the cable laid at the bottom of this trench and covered with incombustible



PLAN


Bottomless steel box drilled and tapped for screws to hold cover
Lug for padlock
Shelf
Floor
Cinder block
Bottom of cable trench

ELEVATION
Front cover removed

Figure 3.- Cable junction for buried power cable.

material, the possibility of fire or of the cable being damaged by derailed cars and locomotives is very remote. Planks may be used as supplementary protection over the cable at places where men may dig ditches.

When the trench is taken under the mine tracks, the depth should be increased substantially to make certain that the cable will not be subjected to any crushing loads imposed by passing locomotives and trips. If a greater depth is undesirable for any reason, the additional protection should be obtained by a heavy metal or concrete duct under the tracks.

SPLICES AND JUNCTION BOXES

The number of splices in underground power circuits ordinarily will be governed by the lengths of cable that can be taken into the mine conveniently. This, in turn, will be controlled by the maximum size of real that can be put on the cage and mounted on a mine car for transportation into the mine. Unreeling the cable as the installation proceeds, rather than dragging it into place, obviates possible damage by cutting and abrasion of the outer coverings.

In one installation where paper-insulated lead-covered cables, in 500-foot lengths, were buried in trenches, open joints were made in concrete boxes set in the floor. A sheet-iron cover for each box completed the protection of the splice. This type of installation would require exceptionally dry conditions to prove satisfactory. For the usual damp atmosphere prevailing in mines, together with ordinary accumulations of water, open joints in such circuits have little if any merit where safety and reliable service are such important factors.

In other trench installations, the splices are housed in sheet-steel boxes recessed in the rib and bricked or concreted in place. The steel cover usually is bolted to the box and flush with the coal. By setting the cable joint back in the rib, the box inclosure can b raised above the floor, thus reducing the possibility of water en it. This arrangement works well in mines having inside portable su stations. In such instances the splices have been made with separab plugs, which can be parted for inserting a receptacle to take the plug from the cable that feeds the motor-generator set in the portable substation and for isolating any section should it be necessary to test for faults. Figure 3 illustrates the type of construction used in a western Pennsylvania coal mine, in which space has not been provided for the substation plug and receptacle. It will be noted that the joint rests on a shelf, from which it can be brought forward by bending the cable.

A number of methods have been used in joining the ends of cables during the installation of high-tension circuits. With suspended steel-armored cables, the bolted cast-iron splice box filled with compound frequently is employed to protect the completed splice. Difficulty experienced with metal splice boxes, attributed to "sweating", has led one company to abandon them in favor of a tube of insulating material filled with compound. Circulating currents set up in the splice box may cause an excessive rise in temperature and give trouble.

To insure against break-down at splices, there is no doubt that careful workmanship is most important. This point was stressed by an engineer for an anthracite company. He pointed out that the secret of its success with the cast-iron splice boxes lay in care taken when the boxes are filled. In the first place, there must be no moisture in the box when filling begins, and the box must not be cold. Heating the box insures that moisture is dried out and also prevents undue chilling of the compound that would otherwise stop its free flowing and thus result in the forming of voids. The practice followed by this company in filling a box is to tilt it at an angle with respect to its longitudinal axis and introduce the melted compound through the lower of the two filler holes, which are at the ends of the box. To do this, a tube or standpipe of sufficient length is placed in the lower hole to insure that the compound will rise the full length of the box, driving out the air as it rises.

One coal company does not use splice boxes with cables not having metallic armor. After the conductor ends are joined with solderless connectors, the individual conductor joints are insulated with rubber tape followed by friction tape. The taped places are next heated gently with a torch, which causes the rubber tape to seal against the entrance of moisture. It would appear that this method would not recommend itself, particularly in wet mines, unless utmost care were taken to see that an adequate amount of insulation was applied properly. One cable manufacturer recommends that "for voltages above 600 and where the cable is liable to long immersions in wet soil, splice boxes" be used. For the wet conditions often existing in coal mining, this recommendation would be applicable.

The method of splicing and jointing nonmetallic and metallic sheathed cables, as recommended by another manufacturer, is as follows:

> "1. The cable ends are brought together and cut off at the center of the joint and the outer coverings removed for a suitable distance. The fiber sleeve and end caps illustrated above (fig. 4) are then slipped back over the cable ends to be assembled after the cables are joined and insulated. 2. The rubber-faced tape is removed from the individual conductors, which are spread radially if multiple-conductor cables are being spliced, and sufficient of the rubber insulation removed to permit applying the connectors,

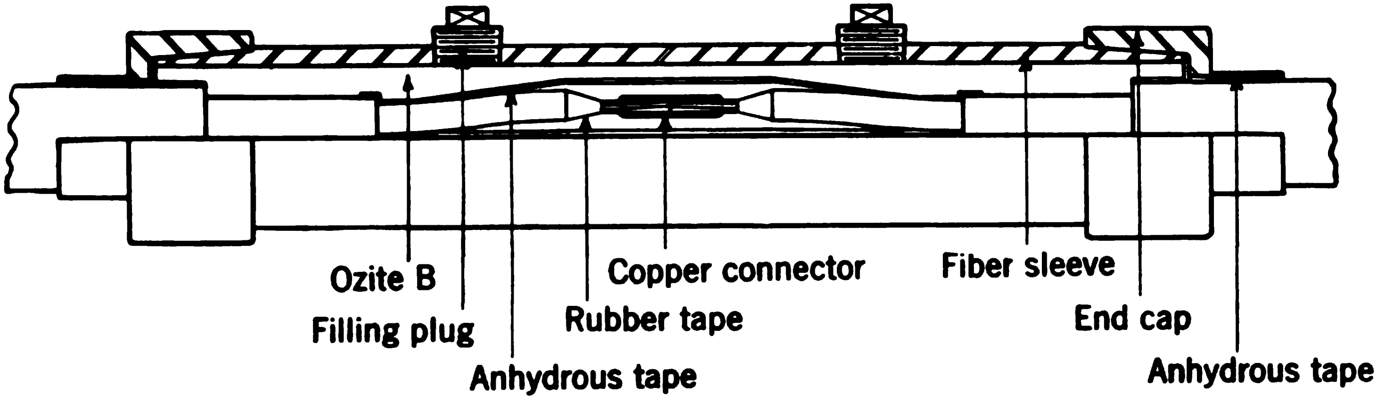


Figure 4.— Typical splice on nonmetallic armored cable.

which are soldered (double-ladle method recommended), and wiped clean, exercising care to see that all solder-tips are well removed and the end edges of the sleeve are rounded off. 3. After penciling off and dressing smooth the edges of the insulation, taking care not to damage the tinning or conductor, the exposed surfaces are coated with rubber cement, which is allowed to set. Then apply a tight well-lapped wrap of rubber insulating tape across the splice from rubber edge to rubber edge, and thereover, enough additional wraps of rubber insulating tape to provide a rubber wall over the connectors approximately 1-1/2 times the thickness of the original factory-applied rubber insulation. 4. The applied insulation is then protected by a wrapping of anhydrous tape. On multiconductor-control and signal-type cables the individual conductor splices are staggered to reduce the over-all diameter of the splice. The individual conductors are then brought together and held in place with a binder of anhydrous tape applied with an open spiral to permit compound to flow around the conductors.

'The splice is now ready for the housing, which, in the case of nonmetallic cable, is a fiber joint sleeve. The fiber sleeve is centered over the joint, the end caps forced on the tapered ends of the sleeve, and the cable entrances sealed with anhydrous tape and P & B paint. The joint is then filled with Ozite B and the joint sleeve painted over thoroughly with P & B paint.

"Metallic armored cable joints are made in the same manner as described above, but instead of using a fiber joint sleeve, are housed in split cast-iron joint boxes, which clamp over the cables. Any difference between the actual cable diameter and the cast diameters of the box entrances is closed up by wrapping the lead or armor with anhydrous tape or jute. The tongue and groove on the flange of the box castings are also packed with jute to prevent leakage of compound. The box is then filled with Ozite B.

"In filling the joint sleeve or box, the usual precautions should be taken to insure complete filling and the elimination of air pockets and voids.

"Either type of joint described above may be buried in the ground without any additional protection than that provided for the cable."

GROUNDING

Adequate grounding of the metallic armors or sheaths of power cables in mines is generally held as being necessary to prevent electrolysis.

In fact, grounding is required by the mine law in a number of States. For example, the bituminous-mine law for Pennsylvania states (article XI, section 3, rule 47) that "where lead-covered or armored cable is used, the lead or armor shall be electrically continuous throughout and shall be efficiently grounded." However, it is often difficult to obtain a satisfactory ground in mines. A mine may be dry and the strata formation such that "permanently moist earth" suitable for grounding purposes is unobtainable. When the power cable follows the main haulage road, it is common practice to ground the cable sheath to the bonded rail of the trolley system or, as in some cases, to the return or negative feeder that parallels the track and is connected to it at regular intervals. The objection to the use of track for grounding purposes comes from the fact that faulty bonding or broken bonds may cause the cable sheath to become a part of the return circuit of the trolley system and perhaps seriously damage the cable. Because of this possibility, some coal companies avoid grounding of the cable armor except at the bottom of the boreholes and at the substation or other point where the cable terminates. Where it is at all feasible to do so, it would appear to be preferable to keep the grounding of the armor entirely independent of the trolley return circuit.

For effective grounding of armored cables, it is essential that the armor be made electrically continuous throughout the cable length. If metal boxes are not used at splices, provision will have to be made for connecting the two ends of the armor at each splice. If the splice boxes are metal, the armor ends should be carefully connected to the box to make the circuit continuous. Steel boxes used to house splices should be grounded also. In avoiding the use of the track rail for grounding purposes, artificial grounds made by driving pipes or rods into the floor or by burying plates in charcoal may be necessary, unless satisfactory grounding can be obtained outside of the mine.

PENNSYLVANIA BITUMINOUS MINE LAW

The requirements of the Pennsylvania Bituminous Mine Law, as amended in 1937, regarding the installation of power cables underground are interesting and are as follows:

> "Power and Light Circuits (Article XI, Section three).
>
> 29. All high-pressure wires used inside of the mines shall be subject to insulation tests and with carrying capacity according to the rules of the National Board of Fire Underwriters. All high-voltage circuits entering or installed in mines shall have each or all conductors of the same circuit surrounded with metal armor or metallic conduit so designed and arranged as to permit the conductors to ground to their own sheath in case of damage resulting in a failure of their insulation.

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"High-voltage cables in slopes, drifts, or entries in which hauling, conveying, or traveling is done shall be constantly protected from falls of roof or other conditions that may damage the cables.

"Armored cables installed underground after the passage of this amendment, that are not installed in fireproof protecting conduits, shall be buried in a trench having a depth of not less than 12 inches below any combustible material and where such cables pass under mine tracks they shall be buried in a trench not less than 36 inches below the mine tracks. Adequate precautions shall be taken to provide for conducting stray currents from the armor of the cables so as to prevent electrolysis of the armor. Cables shall not be bent to a radius less than the minimum specified by the cable manufacturer.

"No power wires or cables having what is commonly termed as weatherproof insulation or insulation consisting of braided covering, which is susceptible to moisture absorption from the outer surface to the conductor, shall be installed in any mine.

Power Wires and Cables in Shafts, Slopes and Bore Holes.

"5. All power wires and cables in hoisting shafts or manway compartments shall be highly insulated and substantially fixed in position.

"Shaft and slope cables whose conductors or covering are not capable of sustaining their own weight shall be supported, at intervals not to exceed twenty-five feet, by suitable grips, which cannot cause abrasion of the covering or insulation but shall so support the cable that no grip shall carry more than the weight of the cable between any two successive grips. Where the cables are not completely boxed in and protected from falling material, space shall be left between them and the side of the shaft that they may yield and so lessen a blow given by falling material.

"All power wires and cables installed after the passage of this amendment, in wood-lined shafts, shall be protected over the entire distance traversed in the shafts by a conduit of satisfactory corrosion-resisting material. In all shafts or slopes, inclined 20 degrees or more to the horizontal, all high-voltage power cables shall be supported only by their armor, which armor shall consist of satisfactory corrosion-resisting steel wires having a size of not less than No. 8 B.W.G., and the steel armor shall be attached at the

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top of the shaft or slope to a suitable cable-support, which cable-support, together with the armor, shall be capable of supporting a load equal to ten times the weight of the cable; also the cable shall be placed in that part of the shaft or slope where it will be least subject to damage from falling materials or by moving cages, skips, counterweight, ropes, or parts thereof. High-voltage cables installed in metallic incased bore holes may be supported partially by the conductors of the cable and partially by their armors.

"Cables in Haulage Roads:

52. Where the cables or feed wires, other than trolley wires, in main haulage roads, cannot be kept at least twelve inches from any part of the mine car or locomotive, they shall be specially protected by proper guards.

53. Cables and wires, unless provided with metallic coverings, shall not be fixed to walls or timbers by means of uninsulated fastenings."

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